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Chilling Injury and Alternaria Rot of BELL PEPPERS

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Marketing Research Report No. 536

UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Market Quality Research Division

UNITED STATES DEPARTMENT OF AGRICULTURE
1862 1962
Growth Through Agricultural Progress

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Summary and Conclusions

Mature-green bell peppers were weakened and injured by chilling during storage at temperatures of 32° to 40° F. Chilling injury was manifested by sheet pitting and surface scald on peppers stored at 32°, by deterioration and decay of the calyxes, and by the occurrence of numerous spots of alternaria rot on peppers stored at 32° and 40°.

Sheet pitting occurred on peppers stored at 32° F. and to a limited extent on those stored at 36°, but not on those at 40°. The disorder began to appear in 2 to 4 days on highly susceptible pods stored at 32° and became serious in about 9 days. The condition was evident at 32° and increased after a holding period of 4 days at 65° after storage. Severe sheet pitting detracts from the appearance and damages the quality of peppers, but does not cause total loss. Sheet pitting does not necessarily indicate severe chilling injury unless accompanied by the other symptoms. Sheet pitting was prevented in mature-green peppers by holding them at 50° for 5 or 10 days before storing them at 32°. Red-ripe peppers appeared to be immune to sheet pitting.

Surface scald developed on peppers during storage at 32° F., but was more pronounced after 4 days at 65°. The disorder did not occur on peppers stored at 40°.

The calyxes of peppers were also damaged by chilling temperatures. Although the peppers were stored in ventilated polyethylene bags which provided high humidity, the calyxes lost the fresh, bright-green color at 32° and 40° F. They were damaged by storage at 32° for 9 days, but the injury did not show until the peppers were removed to 65°. Discoloration of the calyxes on about one-third of the peppers was noted at 32° in 12 days. Serious injury to the calyxes developed at 65° after 12 days at 40°, and injury at 40° was visible in 18 days. In longer holding periods the calyxes eventually died and developed alternaria rot.

Pepper pods developed moderately serious alternaria rot after 15 to 18 days at 32° and 40° F. Those held longer were much more seriously affected. Causal fungus was thought to be *Alternaria tenuis* auct.

Mature-green peppers should not be stored at temperatures below 45° F., and the ideal temperature is perhaps about 46° to 48°. Under the most favorable conditions peppers can be stored successfully for only 12 to 15 days. While chilling injury was not a problem at 45° or 50°, pods held longer than 15 days started to ripen, the tips of the broken stem developed bacterial soft rot, and decay from all causes increased.

CHILLING INJURY AND ALTERNARIA ROT OF BELL PEPPERS

Lacy P. McColloch, Senior Plant Pathologist, Market Quality Research Division [1]

Review of the Problem

Mature-green bell peppers are subject to chilling injury and should not be stored at temperatures below 45° F. Each year chilling injury takes its toll of peppers during marketing, because some produce handlers do not know of the sensitiveness of bell peppers to low temperatures.

Chilling injury is caused by low, but nonfreezing temperatures. Such temperatures prevent normal metabolism and cause a gradual weakening and eventual death of the peppers.

Low-temperature storage prior to shipping and overrefrigeration during transit or after the peppers reach the market are the most common causes of chilling injury. Refrigeration of bell peppers prior to shipping is usually motivated by a dull market. Refrigeration is used during transit and after peppers reach the market to prevent ripening and to reduce spoilage. Lower temperatures (32° to 40° F.) than desirable are often used because they are in general use for many other vegetables.

Very little research has been done in the past on the effect of low, but nonfreezing temperatures on peppers. Storage guides have listed proper temperatures for transit and storage of peppers, but chilling injury has not received much publicity.

This study was prompted by the problem of protecting fresh peppers by refrigeration without causing chilling injury. This is part of a broad program of marketing research aimed at reducing spoilage of farm products and maintaining their quality during marketing. The purpose of the study was to determine the time-temperature relationship to chilling injury of bell peppers, determine and describe symptoms of chilling injury, relate the occurrence of alternaria rot to chilling injury, and bring together information needed by produce handlers on the proper temperatures for peppers during marketing.

Lauritzen and Wright (*2*) studied the effect of temperatures and humidities on the development of botrytis rot, especially that from artificial inoculation.[2] A review of their publication is included here because of the statement that 0° C. (32° F.) and a relative humidity of 90 percent was the most favorable condition tested for storage of peppers. Lauritzen and Wright were not aware of chilling injury. They

[1] John T. Worthington, of the Market Quality Research Division, and Cleveland Brown, William Ebersole, and Kenneth Wisner, who were formerly members of the Division, assisted in the investigation.

[2] Italic numbers in parentheses refer to items in the Literature Cited, p. 16.

found that decay developed at 32° F., but considered it would develop too slowly to be a problem. The peppers were not held at higher temperatures following low-temperature storage.

In 1938 Morris and Platenius (*9*) published a study of low-temperature injury to cucumbers and peppers. They considered pitting on these and other commodities observed to be a symptom of chilling injury and studied the effect of temperature and humidity on its development. Both low temperature and low humidity were necessary to cause severe pitting. Pitting was very slight at low temperature if the humidity was high or if the commodity was waxed. They concluded that pitting was not caused initially by desiccation, but that it was caused by injury to certain cells on the epidermis. They stated that primary injury to the surface cells may be produced by low temperature, mechanical injury, or suboxidation.

Source of Peppers Used in Tests

Peppers of the California Wonder variety were grown at the Plant Industry Station, Beltsville, Md., so that carefully handled, fresh material of known history would be available for these tests. Tests were made in 1955, 1956, and 1957 to determine the effect of storage for various periods at 32°, 40°, 45°, and 50° F., on chilling injury and general keeping quality of mature-green pods. Tests with peppers grown in 1958 and 1959 included studies of symptoms of chilling injury and studies of inoculation with *Alternaria tenuis* to find out whether peppers are weakened by low but nonfreezing temperatures. Less extensive studies were made on storage of red-ripe pods and pods turning red.

The pods were washed by a quick dip, to prevent water from entering the small opening in the blossom end of some, and were wiped dry. They were graded for size, shape, soundness, and firmness. Experimental lots were carefully selected for uniformity and testing began within a day after harvest.

Materials and methods used in making the tests are discussed in the sections concerned.

Storage Tests

Mature-green peppers were stored in single-layer fiberboard boxes enclosed in ventilated polyethylene bags at 32°, 40°, 45°, and 50° F., for 9, 12, 15, 18, and 21 days. Temperatures referred to in this report are air temperatures of storage rooms and not commodity temperatures. Test lots were removed at the end of the storage period, and data on the condition of the pods were obtained. After 4 days at 65°, the pods were examined again.

Data were obtained on the condition of the calyxes (whether they were a fresh, green color, dying, or decayed) and the condition of the pods (whether they had sheet pitting, surface scald, or decay). Supplementary data were also obtained on decay of the stems and color development of the pods.

Pods immediately out of storage were in remarkably good condition (table 1). In those stored 15 days there was a loss of greenness of the calyxes of all pods except those stored at 50° F. Peppers stored at 32° had deteriorated the most. Sheet pitting, which occurred only at 32°, was present on a high percentage of pods as they were

TABLE 1.—*Effect of temperature and storage period on calyx and pod condition of bell peppers immediately after storage*

Storage period and temperature (° F.)	Fruits in test	Calyx condition			Pod condition		
		Fresh and green	Dying	Decayed [1]	Alternaria rot	Total rot	Sheet pitting
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
9 days:							
50°	62	100	0	0	0	2	0
45°	102	100	0	0	0	0	0
40°	101	100	0	0	0	0	0
32°	102	100	0	0	0	0	65
12 days:							
50°	63	100	0	0	0	0	0
45°	60	100	0	0	0	0	0
40°	78	100	0	0	0	0	0
32°	78	54	46	0	0	0	68
15 days:							
50°	61	100	0	0	0	0	0
45°	102	95	5	0	0	0	0
40°	120	94	6	0	0	0	0
32°	120	62	38	0	0	0	70
18 days:							
50°	61	98	2	0	0	0	0
45°	88	99	1	0	0	0	0
40°	106	66	34	0	0	0	0
32°	108	18	82	0	0	0	77
21 days:							
50°	60	100	0	0	0	2	0
45°	88	92	8	0	0	1	0
40°	88	59	41	0	0	18	0
32°	88	16	84	20	0	0	81

[1] Included in calyxes dying.

removed from that temperature. Alternaria rot, however, did not become evident until after the post-storage holding period at 65°.

During 4 days at 65° F., following storage at lower temperatures, a striking difference became evident between peppers stored at 32° and 40° and those stored at 45° and 50° (table 2). Those stored at 32° and 40° showed extensive evidence of chilling injury. Pods stored at 32° were injured much more than those at 40°. Injury was evident in those stored at 32° for a moderately short period of 9 days. Calyxes had lost their fresh, green color rapidly and were dying on more than half of the pods. As the storage period at 32° and 40° was lengthened, more and more calyxes showed deterioration and decay, and alternaria rot developed on the pods. Sheet pitting increased appreciably during 4 days at 65° on pods previously stored at 32°. Alternaria rot on the pods became serious following storage at 32° and 40° for 18 days or longer. Surface scald occurred only in lots stored at 32° for 12 days or longer.

Peppers held at 50° F. were free of chilling injury and remained remarkably fresh through 15 days' storage, even after 4 days at 65°. During longer periods at 50° stems developed bacterial soft rot and pods slowly developed yellow and red color. Total decay reached a peak of 22 percent following 21 days' storage at 50°.

Results on peppers stored at 45°

TABLE 2.—*Effect of temperature and storage period on calyx and pod condition of bell peppers after 4 days at 65° F. following removal from storage*

Storage period and temperature (° F.)	Fruits in test	Calyx condition			Pod condition			
		Fresh and green	Dying	Decayed [1]	Alternaria rot	Total rot	Sheet pitting	Surface scald
9 days:	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
50°	62	100	0	0	0	2	0	0
45°	102	100	0	0	0	0	0	0
40°	101	93	7	0	0	2	0	0
32°	102	23	77	0	2	4	76	0
12 days:								
50°	63	97	3	0	0	5	0	0
45°	60	98	2	0	7	7	0	0
40°	78	67	33	0	3	33	0	0
32°	78	0	100	58	5	6	79	36
15 days:								
50°	61	100	0	0	2	5	0	0
45°	102	90	10	0	1	5	0	0
40°	120	26	74	2	3	18	0	0
32°	120	0	100	45	16	24	94	65
18 days:								
50°	61	89	11	0	0	13	0	0
45°	88	74	26	0	2	10	0	0
40°	106	2	98	19	23	42	0	0
32°	108	0	100	64	48	61	94	61
21 days:								
50°	60	78	22	0	0	22	0	0
45°	88	45	55	2	5	18	0	0
40°	88	0	100	35	49	80	0	0
32°	88	0	100	91	78	84	93	88

[1] Calyxes with alternaria rot are included in calyxes dying.

F. were nearly as satisfactory as on those stored at 50°. In fact, ripening and color development were restricted much more at 45° than at 50°. However, loss of the fresh, green color of the calyxes was nearly twice as great at 45° as at 50° after 21 days' storage. A substantial difference was found even in lots stored 15 days, and the spread increased as the storage period lengthened. Loss of fresh, green color of calyxes at 45° indicated that this temperature bordered on being harmful to peppers. Tests were not made, but the optimum temperature for maintaining quality of mature-green peppers during short-term storage is probably about 46° to 48°.

Decay other than alternaria rot was due to bacteria of the soft-rot group and to *Botrytis cinerea* Fr. Bacterial soft rot occurred at 50° F., and botrytis rot occurred mostly at 40°.

Symptoms of Low-Temperature Injury

Sheet pitting, surface scald, and calyx deterioration were found to be symptoms of chilling injury on mature-green bell peppers. Dying of the calyxes has been recognized as a symptom of chilling injury for a

BN–15932

Figure 1.—**Early stage of sheet pitting showing the sheet effect and dappled appearance.**

number of years, but sheet pitting and surface scald are described for the first time.

Sheet Pitting

Occurrence and Symptoms

On seriously affected pods large areas of pits covered half or more of the pod in a "sheet" effect. This type of pitting on mature-green bell peppers has not heretofore been described, and the name "sheet pitting" is proposed as a descriptive name. Sheet pitting occurred on freshly harvested mature-green peppers stored at 32° and to a lesser extent at 36° F., but did not occur at 40° or above. The injury was apparent at the time the pods were removed from low temperature. A few scattered pits were found on an occasional pod after 2 to 4 days at 32°. Sheet pitting increased in severity and number of pods affected during 15 days' storage at 32°, but did not increase much after 15 days at that temperature. After 7 days at 32° about 50 percent of the pods showed sheet pitting. Affected tissues lost moisture and became sunken, and the pits were more evident after 1 to 4 days at 65° following low-temperature storage. The number of pods affected also increased.

Sheet pitting first appeared as water-soaked spots, which were either widely separated or close together. Affected areas were grayish-green, and individual spots were flat or slightly sunken with a small ring of normal tissue surrounding them. En masse, affected areas had a dappled appearance (fig. 1). Affected tissues lost moisture, and the sheet-pitted areas were sunk irregularly and appeared pebbly. The pattern of sheet pitting varied due to size and spacing of pits. Frequently, pods developed numerous small pits in close proximity, which

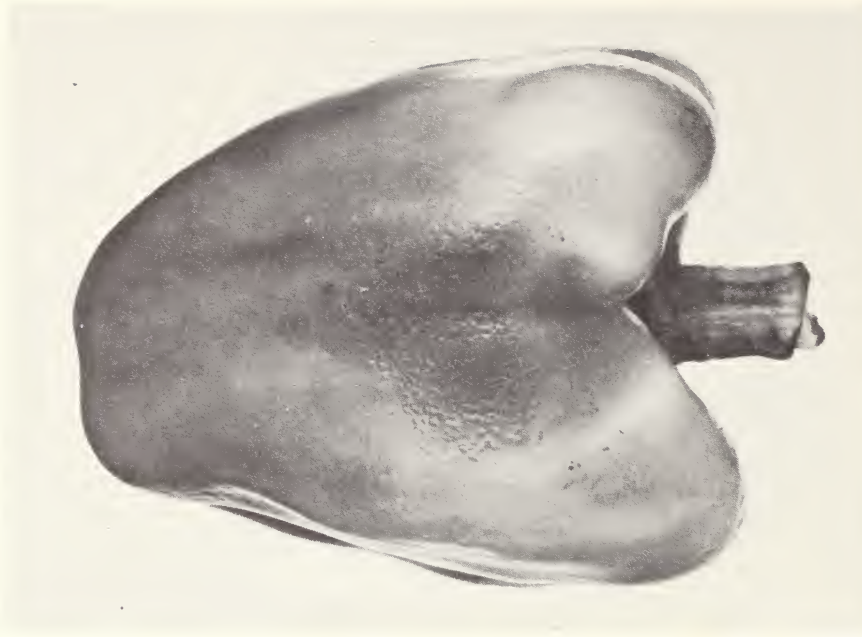

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Figure 2.—**Sheet pitting with numerous small pits, which give the pepper a grainy appearance, is frequently found.**

gave the affected area a grainy appearance (fig. 2). Scattered spots were larger than others and upon losing moisture developed shallow, flat-bottomed pits with definite, but somewhat irregular margins (fig. 3).

Nature of the Disorder

The nature of sheet pitting is not fully understood. It is believed to be different from the pitting on peppers at low temperature discussed by Morris and Platenius (*9*), which was often associated with skin breaks. Pits following skin breaks have a characteristic appearance (fig. 4) that is quite different from sheet pitting. Careful examination of the peppers failed to associate sheet pitting with mechanical skin breaks.

Sheet pitting appeared to follow physiological death of some of the weaker tissues. The disorder was confined to the shaded portion of the pods as they grew on the plant and was never observed on the part most exposed to the sun. Differences in the amount of the pod surface shaded during growth caused variation in susceptibility in all tests. The amount of sheet pitting which occurred at 32° F. appeared to depend more on susceptibility than on an increase in length of storage at 32° beyond about 15 days. Some unknown factors influence susceptibility, as indicated by seasonal variation. Peppers grown in 1957 and 1959 were quite susceptible to sheet pitting, whereas those grown in 1958 developed very little of the disorder during or following 32° storage.

The pitting reported by Morris and Platenius (*9*) was influenced greatly by the relative humidity. For example, no pitting was observed at temperatures above 40° F. at 95 percent relative humidity, whereas some pitting occurred at 40° and 50° when the relative humidity was 55 percent or less. In

BN—15934

Figure 3.—**Typical scattered spots of sheet pitting after the pits lost moisture. Note flat-bottomed pits with somewhat irregular margins.**

the studies reported here sheet pitting did not occur at 40° or above and did not require low humidity to develop at 32°. In these tests peppers were stored in fiberboard trays enclosed in ventilated (twenty-four ¼-inch holes) polyethylene bags, which provided high humidity. The relative humidity of the storage rooms was maintained between 88 and 90 percent. Under such conditions sheet pitting developed on a high percentage of pods at 32° with humidities between 96 and 98 percent (tables 2 and 3). However, the character of the pits was changed by loss of moisture, and certain tests showed that the disorder was increased by lowering the humidity (table 3).

Sheet pitting is the first symptom of chilling injury to appear at low temperature. The condition indicates that peppers have been held for several days at temperatures below 40° F., but it is not necessarily a sign of severe chilling injury. Sheet pitting detracts from the appearance, but does not in itself cause total loss. A few days at 65° to 70° are needed to detect the extent of chilling injury.

Peppers that were turning red were resistant to sheet pitting. Only an occasional pod was slightly affected. Red-ripe peppers were found to be immune, even after 27 days at 32° F.

Conditioning Peppers Against Sheet Pitting

Limited tests showed that mature-green peppers could readily be conditioned against sheet pitting by holding them at 50° F. for 5 or 10 days prior to storage at 32°.

In one test peppers stored immediately at 32° F. for 12, 15, and 18 days were compared with similar peppers held at 50° for 10 days before storage at 32° for 12, 15, and 18 days. In general, peppers stored

BN–15935

***Figure 4.*—Pitting at 32° F. following mechanical skin breaks. Pits slope toward bottom and follow area of wound.**

immediately at 32° developed a serious amount of sheet pitting, whereas with the exception of one instance peppers held at 50° for 10 days before storing at 32° developed no sheet pitting (table 3).

While more peppers had sheet pitting at a relative humidity of 88 to 90 percent than at 96 to 98 percent, the disorder was caused primarily by the low temperature and not by desiccation.

Eighteen days at 32° F. was twice as long as needed to cause serious sheet pitting. This extreme condition was included in order to adequately test whether peppers could be conditioned against sheet pitting by holding at 50° before storing at 32°.

In another test two lots of 60 peppers each were tested to find out what effect holding them at 50° F. before storing them at 32° had on sheet pitting. One lot was immediately put into 32° storage. The other lot was divided into two sublots of 30 peppers each. One sublot was held at 50° for 5 days and then stored at 32° for 14 days; the other was held at 50° for 10 days and then stored at 32° for 14 days. The results were as follows:

Treatment	*Pods with sheet pitting (percent)*
Immediate storage at 32° F. for 14 days	93
5 days at 50°, then 32° for 14 days	0
10 days at 50°, then 32° for 14 days	0

Again, there was a striking contrast between peppers stored directly at 32° F. and those held at 50° for 5 or 10 days before storing at 32° for 14 days.

A change evidently takes place at 50° F. in the tender, shaded portion of the pods that later prevents them from developing sheet pitting. The

TABLE 3.—*Influence of immediate and delayed storage at 32° F. and of two ranges of relative humidity on sheet pitting of peppers*

Storage temperature and holding period	Relative humidity [1]	Fruits in test	Peppers that developed sheet pitting during storage	
			At 32° F.	At 32° F. followed by 4 days at 65°
	Percent	*Number*	*Percent*	*Percent*
32°, for 12 days	96–98	18	33	44
32°, for 12 days	88–90	18	67	72
50°, for 10 days then 32° for 12 days	96–98	18	0	6
50°, for 10 days then 32° for 12 days	88–90	18	0	0
32°, for 15 days	96–98	18	33	39
32°, for 15 days	88–90	18	40	67
50°, for 10 days then 32° for 15 days	96–98	18	0	0
50°, for 10 days then 32° for 15 days	88–90	18	0	0
32°, for 18 days	96–98	18	44	50
32°, for 18 days	88–90	18	56	72
50°, for 10 days then 32° for 18 days	96–98	18	0	0
50°, for 10 days then 32° for 18 days	88–90	18	0	0

[1] Determined by electric hygrometer sensing elements or a sling psychrometer.

nature of the change, however, is not known.

Surface Scald

Peppers were unable to carry on normal metabolism at 32° F. and slowly died. Pods varied considerably in the time required for them to succumb, but many showed signs of death in 12 days. As the tissues became permanently damaged, the skin of the peppers changed from a lustrous, dark green to a dingy grayish-brown color, which gave the pods a dull, lifeless appearance (fig. 5). The condition was recognizable at 32°, but became much more pronounced after 4 days at 65°. The name "surface scald" was used to designate this condition. While some variation was found, surface scald in general grew progressively worse as the storage period at 32° was increased (table 2).

Pods held at 40° F. had less luster than those held at 45° and 50° and developed certain other indications of chilling injury, but did not develop surface scald.

Calyx Deterioration and Decay

Freshly harvested peppers of good quality had bright green, healthy calyxes. Although test lots were enclosed in ventilated polyethylene bags, which provided high humidity, the freshness and luster of the calyxes were visibly damaged at 32° F. during storage periods of 12 to 15 days, and at 40° in 18 days. This was in sharp contrast to peppers stored at 50° in which calyx freshness changed little during 21 days, or those at 45° in which there was a gradual loss of freshness as the storage period was lengthened (table 1). The fresh appearance of the calyxes while at 32° and 40° was deceptive of their true condition, however. The calyxes of chill-injured peppers de-

BN—15936

Figure 5.—**Surface scald is characterized by a grayish-brown color, which gives the pepper a lifeless appearance.**

clined rapidly during holding at 65°, and those sufficiently injured by low temperature developed alternaria rot (fig. 6). A marked contrast remained after 4 days at 65°, following storage, between those stored at 32° and 40° and those stored at 45° and 50° (table 2).

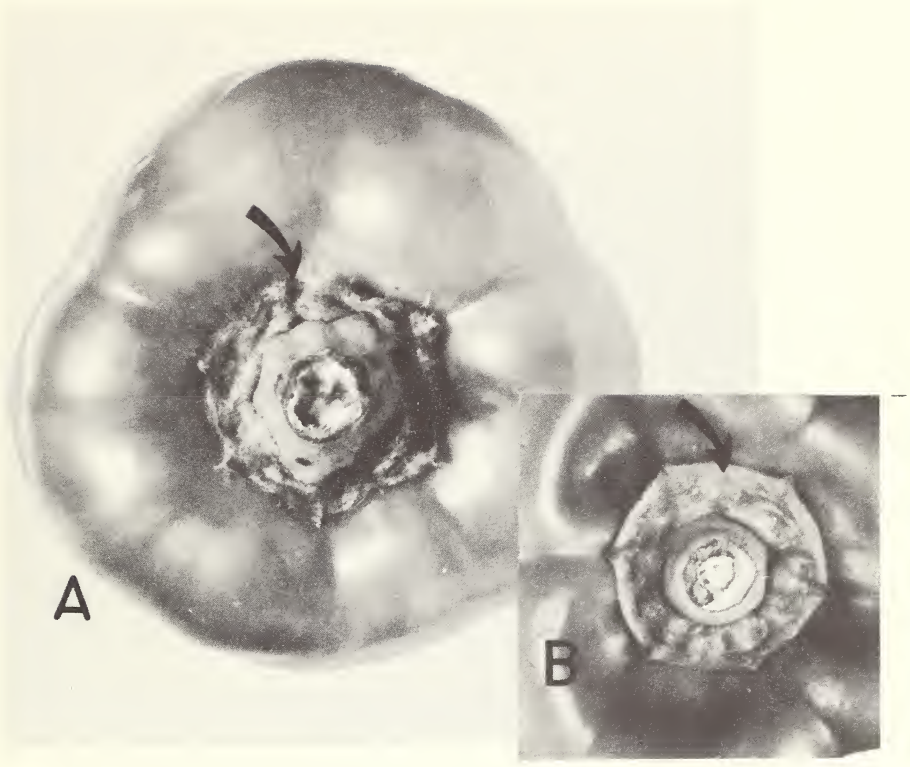
Alternaria Rot

Occurrence, Cause, and Description

Alternaria rot or black spot of peppers was first reported in the United States in 1909 and has been reported since that time in most pepper-producing areas. In the field, alternaria rot was found following sunscald and blossom-end rot or on deteriorating ripe pods. In 1915 Melchers and Dale (*8*) found alternaria rot on peppers following sunscald and frost injury and reported the fungus to be a weak pathogen when inoculated into normal pepper tissue.

Link and Gardner (*4*) were probably the first to list alternaria rot as a postharvest disease of peppers, but they did not elaborate on it. Under present commercial handling practices two factors, in addition to the preharvest conditions listed above, influence the occurrence of alternaria rot on bell peppers after harvest: (1) Severe wounds or crushed tissues followed by a long holding period at moderate temperatures, and (2) chilling injury.

In the brief accounts of alternaria rot on peppers in the United States, most authors listed the causal fungus as *Alternaria sp.* Some, however, thought that two or more species were involved, but no studies were made on nomenclature. Later Groves and Skolko (*1*) reported *Alternaria tenuis* from pepper seeds, and Leyendecker (*3*) found *Alternaria tenuis* as a secondary infection, in the field, on peppers following the physiological disorder blossom-end rot. Neither of these cases, however, was closely enough



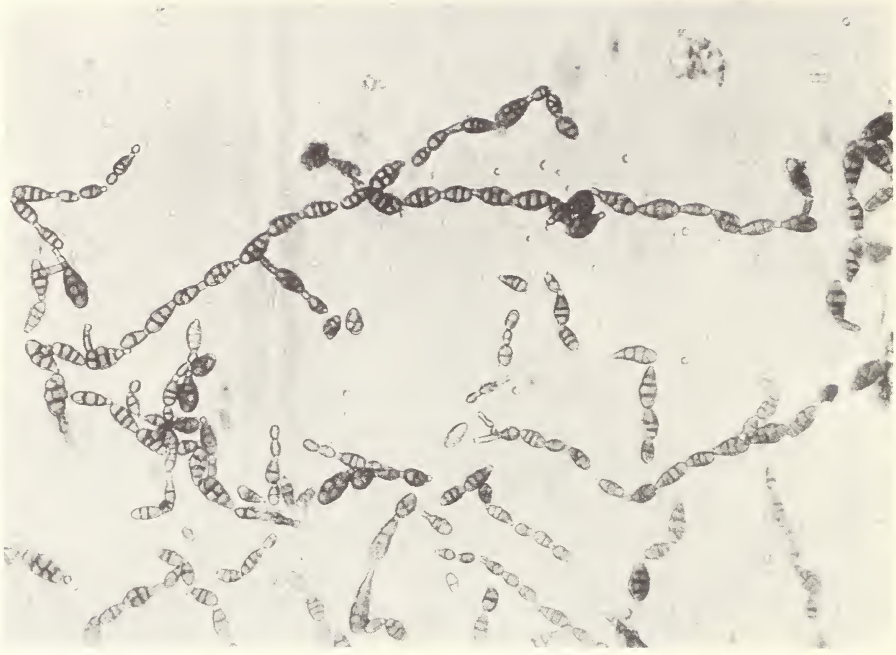
BN—15937

***Figure 6.*—(A) Dead calyx with alternaria rot following storage at 32° F. for 18 days and then held at 65° for 4 days. (B) Healthy calyx from nonchilled pepper.**

associated with the typical alternaria rot of peppers on the market to attract attention or point to *Alternaria tenuis* as the causal agent of the pepper rot. Literature is accumulating which lists *Alternaria tenuis* as the causal agent of the alternaria rot complex of a wide variety of harvested fruits and vegetables. From widely separated areas *Alternaria tenuis* is shown to be omnipresent in nature, and to be a weak pathogen dependent upon weakened or injured tissues and favorable environment to cause infection and decay.

In the studies reported here the *Alternaria* fungus from decaying peppers from several sources was isolated and observed in culture for spore formation and size. While the study was not in the detail reported for alternaria rot of tomatoes (*5*) or acorn squashes (*6*), there was no doubt that the causal fungus was *Alternaria tenuis* auct. (fig. 7).

Peppers did not develop visible alternaria rot during storage periods up to 30 days at 32° F. Alternaria rot developed rapidly, however, after chill-injured peppers were removed to 65° (fig. 8). In the early stages alternaria rot appeared as small, circular, slightly depressed, water-soaked spots with a grayish-green color. In time, affected areas enlarged and became sharply sunken. The surface of the spots ranged in color from tannish brown to muddy brown and eventually turned black. With high humidity gray mycelium covered the spots. If conditions favored spore formation, the decayed sur-



BN–15938

Figure 7.—Isolates from alternaria rot of peppers produced chains of spores typical of *Alternaria tenuis.*

BN–15939

Figure 8.—Typical alternaria rot on chilled peppers.

face developed a dense growth of sporophores and spores that had a greenish-olive color and velvety texture. Internally, old lesions usually appeared black and somewhat leathery, and some had gray mycelium present.

Low Temperature and Alternaria Rot

Extensive alternaria rot followed serious chilling injury of bell peppers in much the same manner as that found on tomatoes (*7*) and acorn squashes (*6*) injured by low, but nonfreezing temperatures. Only a small amount of alternaria rot developed on peppers that were not subjected to 32° and 40° F. storage. Alternaria rot did not become evident at low temperatures during the periods tested, but came on rapidly after the peppers were moved to 65° (tables 1 and 2). Moderate to serious chilling injury occurred at 32° in 15 days and at 40° in 18 days as judged by the percentage of peppers that developed alternaria rot. Peppers held longer developed numerous spots of alternaria rot.

The occurrence of surface scald, the deterioration of the calyxes, and the development of alternaria rot on the calyxes and pods were more reliable indications of severe chilling injury than sheet pitting. Severe sheet pitting can develop at 32° F. in 7 to 9 days, which is too short a period to cause severe chilling injury.

Inoculation Studies

Peppers were inoculated to determine whether those held at low temperatures were more susceptible to alternaria rot, as a result of chilling injury, than nonchilled peppers. Freshly harvested mature-green peppers of good quality were used. Each lot was carefully selected for uniformity of shape, size, and firmness.

The *Alternaria* fungus was grown on cornmeal agar. Cultures about a week old were used. The peppers were washed and swabbed with 95-percent alcohol. Following inoculation the inoculum was covered by damp cotton pads, and the peppers were held in fiberboard trays enclosed in ventilated polyethylene bags.

Several inoculation techniques were tried before one was found that would reflect the weakening effect of chilling injury. For example, a 4-millimeter disk of inoculum inverted over the uninjured epidermis failed to cause decay even on peppers with some chilling injury. In the other extreme, if a 4-millimeter wound was made in the pods and inoculated with a 4-millimeter disk of inoculum a high percentage of nonchilled pods developed decay. In the tests a 4-millimeter disk of inoculum was inverted over a needle puncture after the peppers had been held at 32°, 36°, 40°, 45°, and 50° F. for 14 days. The inoculations were protected from drying out as described above and were incubated for 10 to 16 days at 50°. An infallible inoculation technique was difficult to develop because the *Alternaria* fungus infected so slowly. If the peppers were held at low temperature long enough to cause serious chilling injury, they were consumed by decay from natural infection during the long incubation period. If the exposure to low temperature was too brief, the peppers remained resistant.

Although the conditions for infection were excellent, the *Alternaria* fungus failed to infect certain pods. The data of three tests were averaged; and, while the results were not as consistent as desired, they did show an interesting pattern (table 4). Peppers stored at lower temperatures before inoculation developed a higher percentage of decay and larger decay spots than

those stored at the higher temperatures. This development of decay was progressively larger from storage temperatures of 50° down to 32° F. The data indicate that peppers stored at 40° or below were weakened and were more susceptible to alternaria rot.

TABLE 4.—*Susceptibility of stored bell peppers to* Alternaria *rot after storage at various temperatures*

Storage temperature during 14 days before inoculation	Peppers inoculated	Peppers infected by inoculation [1]	Average diameter of lesions from infection
	Number	*Percent*	*Millimeters*
50° F.	100	51	2. 7
45° F.	72	60	2. 9
40° F.	106	79	6. 9
36° F.	106	87	9. 5
32° F.	94	87	12. 2

[1] After inoculation, peppers were incubated at 50° for 10 to 16 days.

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